Parkinson's Detection: Emotional Intelligence Perspective

Anzah Bashir[1], Khalid Hafiz Mir[2], Yashwant Singh[3]

[1,2]M.Tech. Student, Department of Computer Science and IT, Central University of Jammu, India
[3]Professor, Department of Computer Science and IT, Central University of Jammu, India

Abstract:
Parkinson's disease is a neurological ailment affecting millions of individuals throughout the world. Early detection and accurate diagnosis of Parkinson's disease (PD) are crucial for effective treatment and management of the disease. In recent years, there has been growing interest in using Emotional Intelligence-based approaches to detect PD, as changes in emotional processing are a common symptom of the disease. Emotion recognition using various techniques of emotional intelligence can aid in early detection, management, and monitoring of the disease. This paper presents a comprehensive review of the research on PD detection. Also, the taxonomy approaches to PD detection using different biomarkers and Emotional Intelligence (EI) are discussed. In this paper, it also reviews recent studies on the use of Emotional intelligence techniques for PD detection and proposes future directions for research in this area. Overall, the review suggests that using Emotional Intelligence approaches has a high potential for enhancing the accuracy and reliability of PD detection and monitoring, and can have significant implications for improving the quality of life of PD patients.

Keywords: Parkinson's disease (PD), Emotional Intelligence (EI), Motor and non-motor symptoms

1. Introduction

Parkinson's disease (PD) is a neurodegenerative disorder that affects movement and coordination. It is caused by the degeneration of dopamine-producing neurons in a specific part of the brain called the substantia nigra. The decline in dopamine levels leads to symptoms such as tremors, stiffness, slow movement, and difficulty with balance and coordination [1].The exact cause of Parkinson's disease is unknown, but it is believed to be a combination of genetic and environmental factors may be responsible for this condition[2][3][4]. Age is also a significant risk factor, as the majority of cases occur in individuals over the age of 60 [5]. PD is diagnosed by a careful review of symptoms, physical examination, and medical history. There is no specific test for Parkinson's disease, but imaging tests such as CT scans or MRI may be used to rule out other conditions [6]. Treatment for Parkinson's disease is primarily focused on managing symptoms and improving quality of life. This may involve medications to increase dopamine levels, physical therapy to improve mobility and balance, and lifestyle changes such as exercise and diet modifications. Living with Parkinson's disease can be challenging, and individuals may experience a range of physical, emotional, and social effects.

Parkinson's disease can have a significant influence on Emotional Intelligence, and individuals with the condition may experience changes in mood and Emotional regulation, difficulties with social interactions and communication, and changes in executive functioning. These changes can result in decreased

Emotional Intelligence and affect an individual's ability to understand and regulate their emotions, as well as perceive and respond to emotions in others. The physical symptoms of Parkinson's disease can also have an adverse effect on one's emotional well-being. According to research, people with Parkinson's disease may suffer changes in mood and emotional control, such as depression and anxiety. For example, a study published in the Journal of Parkinson's Disease discovered that around 50% of people with Parkinson's illness experience depression, which can significantly impact Emotional Intelligence [7].In addition to changes in mood and emotional regulation, individuals with Parkinson's disease may also experience difficulties with social interactions and communication. A study found that people with Parkinson's disease may experience decreased social competence, which can impact their ability to effectively navigate complex emotional and social situations [8].Executive functioning, which includes working memory, cognitive flexibility, and decision making, can also be impacted in individuals with Parkinson's disease. A study published in the Journal of Neurology found that individuals with Parkinson's disease may experience changes in executive functioning, which can result in difficulties with problem solving, decision making, and adapting to changing situations [9].Finally, the physical symptoms of Parkinson's disease can also have a significant impact on emotional well-being. These symptoms can cause embarrassment and reduced self-esteem, which can result in social isolation and decreased Emotional Intelligence. Despite these challenges, those suffering from Parkinson's disease can still maintain and enhance their emotional intelligence through various means. This may involve participating in cognitive and emotional therapies, engaging in physical and mental activities, and seeking support from family, friends, and healthcare providers. Therefore, Parkinson's disease can have a significant impact on Emotional Intelligence, but with the right support and strategies, individuals with the condition can still maintain and improve their Emotional Intelligence.
Section 2: Start with an overview of PD and its prevalence. Section 3: It gives us the brief information about the detection of Parkinson's disease using different biomarkers and non-invasive methods. Section 4: It define the Emotional Intelligence, how it can be affected by PD and discuss the models of Emotional Intelligence. Section 5: This section provides the Literature review of PD detection technique. Section 6: Future Directions and conclusion.

2. Parkinson's disease

After Alzheimer's, Parkinson's disease (PD) is the most prevalent neurological illness. Parkinson disease (PD) is a degenerative neurological illness of the brain's central nervous system [10]. It is a multifactorial, a persistent neurodegenerative disease of the peripheral nerve system that destroys nerve cells in the brain. In this scenario, dopamine is produced by neurons in the central brain and functions as a neurotransmitter (chemical transfer message) to analyse the patient's hormones in any mood. PD is liable for the deaths of DNs in the human brain's Substantia Nigra (SN) region. Dopamine is a neurotransmitter that affects emotion, thought, and action. A person with Parkinson's disease may also suffer from restlessness, despair, anxiety, pain, weariness, constipation, and trouble learning, all of which have a substantial influence on their everyday life. The human brain has the most neurons at birth, but the neurons die and become irreparable with time [11].Parkinson's disease is generally identified 10-15 years after beginning, or until the DNs die or their dopamine levels decline. When 60% of dopaminergic neurons begins to decrease, symptoms occur; only then is a suitable therapeutic option conceivable. Parkinson's disease symptoms include changes in posture, loss of balance, slowness of movement, severe tremor, difficulty to measure alone, and inability to stand or walk [12]. Parkinson's disease affects 0.3% of the general population, varied by nation, and rising to 1-3% among the elderly. According to the Parkinson's Disease Foundation, around 1 million People are affected by the disorder. In the United States, the incidence of Parkinson's disease is around 20 cases per 100,000 people per year (60,000 occurrences each year), with an average onset age of around 60 years. Parkinson’s disease is estimated to afflict 1% of persons aged 60 and above, increasing to 1% to 3% of those aged 80 and up [13]. It is important to emphasise, however, that these figures do not include undiagnosed cases. Because Parkinson's disease is so complicated, there is presently no viable treatment. The illness is thought to be caused by the death of 70-80% of dopaminergic neurons in the substantial nigra (SNs) portion of the brain, as seen in fig. Dopamine is a neurochemical generated in the substantia nigra, an important brain region, and it influences a number of central nervous system activities, including movement control, executive functions of cognition, and limbic emotional activity.

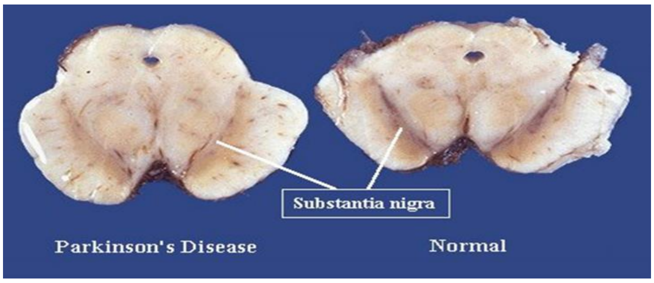

Figure 1 .Demonstrates the death of approximately 70-80% of dopaminergic neurons in the substantial nigra (SNs)

2.1. Symptoms of Parkinson’s disease

Parkinson's disease is a progressive neurological disorder that affects millions of people worldwide. It is characterized by a range of motor and non-motor symptoms that can significantly impact a person's quality of life as shown in table;

Table 1. Symptoms of Parkinson’s disease

Motor Symptoms	Non motor symptoms
Tremors, bradykinesia, rigidity, postural instability	Cognitive impairment, bradyphrenia
Decreased arm swing, shuffling gait, difficulty arising from chair, turning in bed	Sensory symptoms: anosmia, ageusia, pain (shoulder, back), paraesthesia
Micrographia, cutting food, feeding, hygiene slow activities of daily living	Sensory symptoms: anosmia, ageusia, pain (shoulder, back), paraesthesia
Glabellar reflex, blepharospasm, dystonia, stratal deformity, scoliosis, camptocormia	Dysautonomia, weight loss
Hypomimia, dysarthria, dysphagia, sialorrhoea	Depression, apathy, anhedonia, fatigue, other behavioural and psychiatric problems

2.2. Risk concerns

Some of the risk connected with Parkinson's disease are as follows:

(I) Age: Parkinson's disease in young adults is uncommon. It usually starts in the middle or late stages of life, and the risk grows with age. The condition often affects adults over the age of 60 [14]. (II)Sex: Males are more prone than women to get Parkinson's disease. Men had 1.5 times increased relative chance of developing Parkinson's disease than women. (III) Heredity: If you have a close family who has Parkinson's disease, you are more likely to get the disease. Unless you have a significant number of Parkinson's disease relatives in your family, however, your chances of having the condition are low [15]. (IV) Toxins exposure: Continuous exposure to herbicides (chemicals used to kill or control particular types of pests) and pesticides (chemicals used to kill or repel pests of various kinds, including insects and plants on occasion) may increase your risk of Parkinson's disease [16].

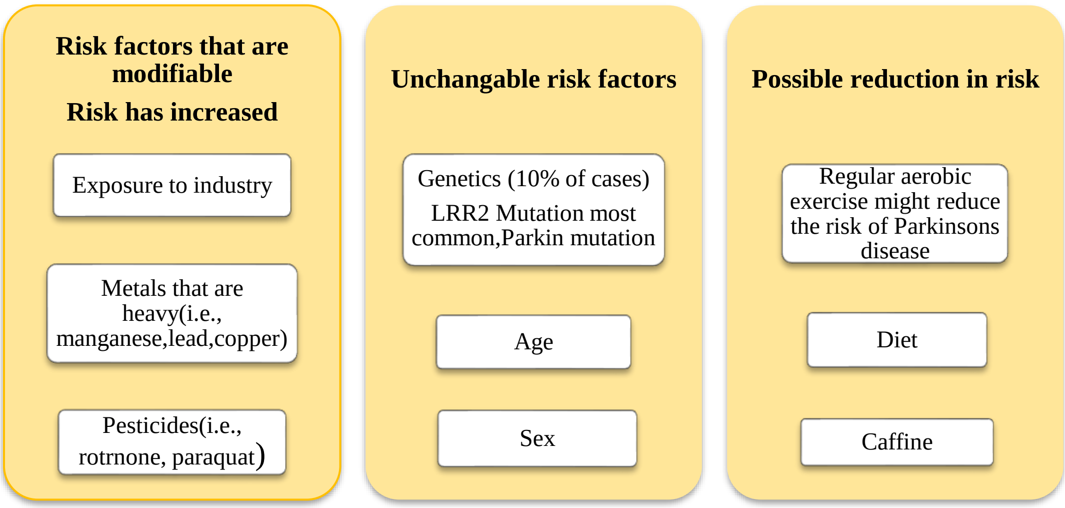

Figure 2.Risk concerns of Parkinson's disease

3. Parkinson's Disease Detection

Parkinson's disease has no particular test. A neurologist (a doctor who specialises in nervous system ailments) diagnoses Parkinson's disease based on your signs and symptoms, medical history, and a neurological and physical examination. Because Parkinson's disease is commonly misdiagnosed in its early stages, we use a number of reliable genetic biomarkers and non-invasive approaches to identify it. Differentiating Parkinson's disease from other diseases, tracking its course, or suggesting a beneficial response to a therapy intervention. The identification of biomarkers, which are perceptible and measurable changes in the body that may be used to predict, diagnose, and track disease activity and development — is the holy grail of invasive Parkinson's disease research. A variety of strategies can be used to discover biomarkers, including Diagnostic markers [17], Progression markers [18], Pharmacokinetic marker [19]. In addition, researchers have developed a number of non-invasive approaches for determining the severity of Parkinson's disease, including acoustic analysis of voice sounds, physiological signals, wearable sensors, and gait analysis. The identification of Parkinson's disease progression through acoustic analysis of speech waves has caught the interest of numerous academics [20].

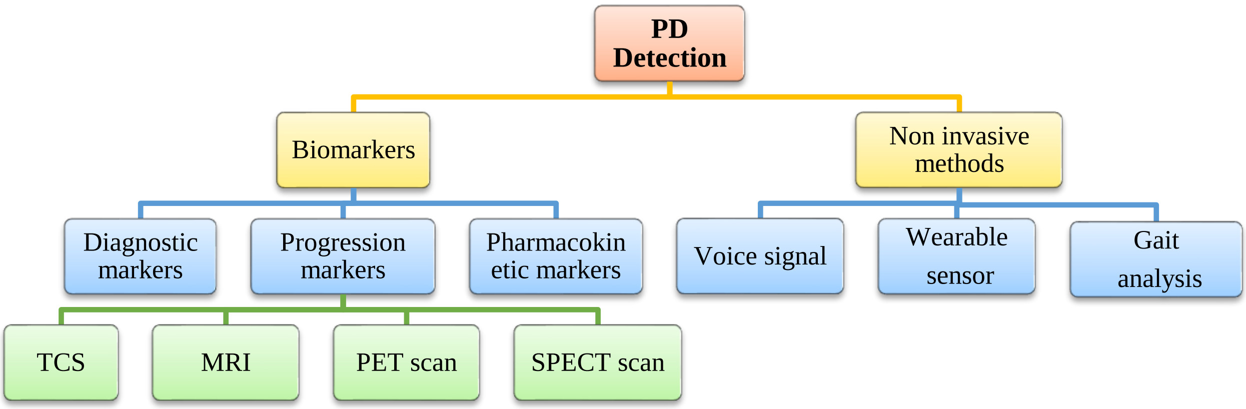

Figure 3. Taxonomy of PD detection using different biomarkers and non-invasive methods.

3.1. Progression markers

Progression marker is further divided into following types:

(I) TCS: Transcranial B-Mode Sonography (TCS) assesses the blood flow velocity of brain arteries by measuring the frequency of ultrasound waves and their reflections. This low-cost and reliable method indicates increased echogenicity of the substantia nigra (SN) in Parkinson's disease (PD) brains compared to the control group, which may be due to heightened iron and gliosis levels in PD patients' SN. Patients with other parkinsonian illnesses, on the other hand, are more frequently hyperechogenic [21].(II) MRI: The most extensively utilised diagnostic paradigm for early identification of Parkinson's Disease is the examination of magnetic resonance imaging (MRI) images of the brain. The MRI scans provide anatomical information about the brain's subcortical structure, which are subsequently evaluated for aneurysms, allowing for early identification of a specific form of sickness. Magnetic Resonance Imaging (MRI) in Parkinson's disease patients can detect changes in brain structure caused by dopamine depletion. can reveal changes in brain structure induced by dopamine depletion [22].(III) PET Scan: Positron emission tomography (PET) scanning is a medical imaging technique that produces pictures of the inside of the body using a small quantity of radioactive material and a particular camera. PET scans are utilised in the setting of Parkinson's disease (PD) to visualise the activity of specific areas of the brain and to aid in the diagnosis of PD. PET scans can assist determine the existence of dopamine-producing cells in the brain in Parkinson's disease, which is important for the diagnosis of PD as a degeneration of dopamine-producing cells is a hallmark of the disease. By measuring the activity of these cells, PET scans can help differentiate PD from other conditions with similar symptoms, such as essential tremor or multiple system atrophy. Studies have shown that PET scans are effective in detecting the presence of dopamine-producing cells in the brains of individuals with PD [23].(IV) SPECT Scan: Dopaminergic imaging, a neuroimaging technique that uses single photon emission computed tomography (SPECT) with I-Ioflupane, is widely used in the early stages of Parkinson's disease[24].Functional neuroimaging using the SPECT approach is beneficial in individuals exhibiting early indications of parkinsonism[25].

3.2. Non-invasive methods

Non-invasive methods is further divided into following types

(I) Voice signal: Voice analysis is a technique that uses computational methods to analyse speech and voice patterns for the detection of Parkinson's disease (PD). It involves recording and analysing speech and voice parameters, such as pitch, volume, and rhythm, to identify any deviations from normal speech patterns that may indicate PD. Studies have shown that individuals with PD often exhibit distinctive speech and voice changes, such as reduced volume and monotony, and altered prosody, which can be detected through voice analysis. These changes can be used to distinguish between individuals with PD and healthy controls, and may provide an early warning of the onset of the disease [26]–[28].(II) Wearable sensors: Wearable sensors are devices that can be attached to the body and used to monitor various physiological signals, such as movement, heart rate, and body temperature. In recent years, wearable sensors have been increasingly used in the field of Parkinson's disease (PD) research and management. Wearable sensors in Parkinson's disease enable for continuous, real-time monitoring of motor and non-motor symptoms such bradykinesia, tremors, and gait abnormalities. This information can be used to track disease progression, evaluate the efficacy of treatments, and monitor the response to therapy [29].(III) Gait analysis: Gait analysis is a technique used to assess and evaluate an individual's walking patterns and movements. In the realm of Parkinson's disease research (PD), gait analysis is used to assess the effects of PD on an individual's gait, as well as to evaluate the efficacy of treatments for PD. Gait analysis in PD can be performed using various techniques, including laboratory-based gait analysis, in-clinic gait analysis, and community-based gait analysis. Laboratory-based gait analysis typically involves the use of high-tech equipment, such as motion capture systems and force plates, to measure various gait characteristics, such as stride velocity, stride length and step length. In-clinic gait analysis typically involves a clinician observing and assessing an individual's gait during a physical examination. Community-based gait analysis involves the use of wearable sensors, such as accelerometers, to measure gait parameters in a real-world setting [30].

4. Emotional Intelligence

Emotional intelligence (EI) is the ability to identify, express, and feel emotions, as well as control them, harness them for constructive goals, and successfully handle the emotions of others. It has been stated that emotional intelligence talents are a better predictor of life success than IQ [31].

Emotional intelligence is commonly defined by four characteristics: (I) Self-awareness – Understanding how one's emotions, emotional triggers, strengths, weaknesses, goals, values, and objectives influence one's thoughts and behaviour is referred to as self-awareness. You understand how your emotions impact your thoughts and actions. You are confident in your abilities while still being mindful of your flaws [31]. (II) Self-management- The ability to control one's emotions, based on self-awareness, is referred to as self-management. Even people with high EQs have bad moods, impulsive behaviours, and negative emotions like tension and rage on occasion. The capacity to regulate your emotions rather than allowing them to rule you is referred to as self-management [32]. (III) **Social awareness** - You're sympathetic. You can recognise emotional cues, understand people' desires and concerns, feel at ease in social situations, and understand power dynamics in a team or organisation. (IV) Relationship management - Relationship management is all about interpersonal skills, which include the capacity to win co-workers' genuine trust, rapport, and respect. It's about more than simply a trust fall during a team building activity; it's about trusting and being trusted as a member of a team. You know how to build and maintain strong relationships, communicate clearly, encourage and influence others, work effectively with others, and handle conflict [33].

4.1. **How Parkinson's disease can affect Emotional Intelligence:** Parkinson's disease (PD) is a neurodegenerative disorder that primarily affects motor function, but it can also impact emotional and social functioning. Emotional intelligence (EI) is a set of skills that enable individuals to recognize, understand, and regulate their own emotions, as well as the emotions of others. In this response, I will discuss in detail how Parkinson's disease can affect emotional intelligence. (I)Recognition of emotions: The ability to recognize emotions is an important component of emotional intelligence. People with PD may have difficulty recognizing emotions due to changes in the brain that affect emotional processing. These changes can make it difficult to identify and differentiate between different emotions, especially those that are subtle or complex [34]. (II)Understanding of emotions: Understanding emotions involves being able to comprehend the reasons behind an emotional response. Individuals with PD may struggle with this aspect of emotional intelligence due to changes in the brain that impact cognitive function. These changes can make it difficult to interpret social cues and understand the motivations behind other people's emotions. (III)Regulation of emotions: Regulating emotions involves the ability to manage and control one's own emotions in different situations. People with PD may experience difficulty regulating their emotions due to changes in the brain that impact the production of neurotransmitters such as dopamine. This can lead to increased emotional instability, impulsivity, and anxiety, which can affect their ability to make decisions and cope with stress [35]. (IV)Communication of emotions: Effective communication of emotions is an important component of emotional intelligence. People with PD may experience difficulty communicating their emotions due to changes in the brain that impact speech and language function. This can lead to difficulty expressing emotions clearly, which can result in frustration and social isolation [36]. (V)Empathy: It involves the ability to understand and share the emotions of others. People with PD may experience difficulty with empathy due to changes in the brain that impact emotional processing and social cognition. This can make it difficult to recognize and respond to the emotional needs of others, which can lead to social isolation and interpersonal difficulties. Therefore, Parkinson's disease can impact emotional intelligence in a variety of ways, including changes in emotional recognition, understanding, regulation, communication, and empathy. However, the impact of PD on emotional intelligence can vary depending on the individual and the stage of the disease. People with PD may benefit from interventions that focus on improving emotional regulation, communication skills, and social support to help mitigate the impact of PD on emotional intelligence and improve their overall quality of life [37].

4.2. Models of Emotional Intelligence

The three key theorists in Emotional Intelligence research are Bar-On, Mayer and Salovey, and Daniel Goleman. Emotional intelligence, according to Reuven Bar-On, a well-known researcher and the inventor of the term "emotion quotient," is concerned with understanding oneself and others, relating to people, and adapting to and coping with one's immediate surroundings in order to be more successful in dealing with environmental demands. (Bar-On, 1997).

The ability model, trait model, and mixed model are the three fundamental branches of emotional intelligence. (I)**Trait model:** In 2001, Konstantinos V. Petrides developed the trait model, which is based on self-reporting of behavioural tendencies and perceived talents. The trait EI model incorporates the Goleman model. When EI is seen as a personality attribute, a construct that is not included in the taxonomy of human cognitive ability arises. This distinction is significant because it influences how the notion is operationalized as well as how theories and hypotheses are developed around it [38].(II) **Ability model:** The ability model, developed by Peter Salovey and John Mayer in 2004, focuses on a person's ability to acquire emotional input and successfully navigate social settings. The definition of EI proposed by Salovey and Mayer aims to fit EI inside the parameters of the accepted standards for a new intelligence. They changed their original definition of emotional intelligence (EI) to "the ability to recognise emotion, integrate emotion to facilitate cognition, comprehend emotion, and control emotion to promote personal growth" as a result of their ongoing study. Their concept of EI, however, changed as a result of their further study to "the capacity to reason about emotions, and of emotions, to increase thinking. It encompasses the skills needed to effectively identify emotions, access and produce emotions to support cognition, comprehend emotions and emotional knowledge, and control emotions in a thoughtful manner to foster both emotional and intellectual development [39].(III) **Mixed model:** Both Goleman's (1995) and Bar-(1997) On's mixed models of emotional intelligence incorporate the value of competency (capacity) as well as general disposition (trait). The concept of a hybrid model is both wide and sound. The difficulty with the mixed model is that it is redundant with personality traits. The mixed model does not just measure emotional intelligence since it focuses on adaptive functioning such as social skills, stress management, and drive.

5. Related works

Literature review of PD Detection techniques using AI techniques:

Pir Masoom Shah et al**.** have devised a technique for detecting Parkinson disease that makes use of a brain MRI scan and CNN for enhanced performance [40]. Matthew P. Adams1 et al. aimed to analyse and anticipate a patient's motor function as measured by part III of the universal Parkinson's disease rating scale (UPDRS) using a convolutional neural network that used the entire DAT image without feature extraction (CNN). [41]. Khatamino et al. proposed an 88% accuracy deep learning CNN-based approach for medical diagnosis based on spiral drawings of Parkinson's disease patients [42]. Dan Long et al. used SVM to classify early PD and HC. In their investigation, they used multimodal MR imaging on each PD and HC patient. Their model has an accuracy of 86.96% [43].Xinjie Shi et al. presented a method for identifying PD and normal patients using hybrid convolutional recurrent neural networks, which is useful in clinical practise [44].Shivangi et.al. suggested a way for distinguishing between Parkinson's disease and normal individuals using hybrid convolutional recurrent neural networks that is beneficial in clinical practise [45]. Ramzi M. Sadek et al. proposed using physical symptoms to detect Parkinson's disease patients as soon as feasible using an artificial neural network using back propagation approach. [46].Krishnagopal S et al. created a network-based technique called Trajectory Profile Clustering (TPC) to detect illness subtypes and past forecasts of disease development trends. It is an excellent method for finding and predicting subgroups in several longitudinal datasets as well as in individual individuals. This results in a 72% accuracy in predicting patients less than 4 years in advance [47]. O. Asmae et colleagues employed ANN and k-NN to discriminate between PD and healthy individuals. In the case of ANN, 70% of the data was utilised for training, 5% for validation, and 25% for testing. ANN claimed an accuracy of 96.7%. They used the RFE approach to perform feature selection (FS) on a dataset.[48].Hetav Modi et al suggested a PD recognition system based on a VGG16-based convolutional neural network (CNN). It extracts characteristics from the PET scan image dataset obtained from the PPMI source automatically. Specificity, accuracy, sensitivity, and precision of the suggested system are 97.5%, 84.6%, 71.6%, and 96.7%, respectively [49].

Table 2 Comparative analysis of PD using different AI techniques

Year	Author	Technique	Dataset	Accuracy
2018	Pir Masoom Shah Et.al [40]	CNN	PPMI	96.2%
2018	Matthew P. Adams1 et al [41]	CNN	DAT SPECT image	70.7%
2018	Khatamino et.at, [42]	Deep Learning system based on CNN.	PPMI	88%
2016	Dan Long et al [43]	SVM	MRI Multimodal scans	86.96%
2019	Xinjie Shi et al. [44]	Hybrid convolutional recurrent neural networks	Raw EEG data	81.13%
2019	Shivangi et.al. [45]	Deep dense ANNs and CNNs	VGFR Dataset	VGFR Spectrogram Detector accuracy = 88.1%, Voice Impairment Classifier accuracy = 89.15%.
2019	Ramzi M. Sadek et al. [46]	SVM	Gene expression database	NA
2020	Krishnagopal S et al. [47]	CART, SVM, ANN	Longitudinal data	72%
2020	Asmae et al [50]	ANN	Private dataset	79.31%
2020	Z.K. Senturk [48]	ANN, CART	Private dataset	91%,90%
2021	Hetav Modi et al [38]	VGG16 based CNN	PPMI	84.6%

Literature review of PD detection techniques using EI:

Shunans Zhao1 et al. proposed categorising emotional speech in Parkinson's disease patients, as well as categorising PD speech. Participants said short words with diverse emotional prosody, which were subsequently recognised using 209 separate audio characteristics and three algorithms (random forests, nave Bayes and support vector machines). When recognising emotions and PD vs. control, they attain accuracies of 65.5% and 73.33%, respectively[51].M. Capecci∗, L. Ciabattoni et al. demonstrate a

Machine-Learning Based Emotion Recognition System in Parkinson's disease patients. This system's development is built of each user executing an experimental protocol while a basic gadget (i.e., wristwatch) worn on the wrist collects data. To detect emotions during the experimental process, a nine-point clinical scale and commercial emotion identification software were employed [52]. Anusri U et al. suggested a study that would use the facial emotions of Parkinson's disease patients and normal people to identify facial emotions such as sadness, happiness, rage, and depression. They attain their performance in terms of accuracy, sensitivity, and specificity by utilising the CNN architecture of Alex Net and Vgg 16 [53].Justyna Skiba´nska has revealed a unique approach to detecting Parkinson's disease based on facial feature expression. The XGBoost classifier beat the others, with 0.69 balanced accuracy. [54]. Konstantinos Sechidis et al. offer a study that uses machine learning approaches to explore the emotional content of speech in Parkinson's disease (PD) patients. It finds speech patterns that are predictive of PD patients' emotional states and compares the effectiveness of several machine learning algorithms in predicting these features. [55]. Muhammad Najam Dar et al. present a 1D-CRNN-ELM architecture that integrates a one-dimensional Convolutional Recurrent Neural Network (1D-CRNN) with an Extreme Learning Machine (ELM), which is resilient for emotion recognition in Parkinson's disease patients[56].

Table 3 Comparative analysis of PD using Emotional Intelligence

Author	**Year**	**Objective**	**Algorithm**	**Accuracy**	**Dataset**
Shunans Zhao1 et al. [51]	2014	Creation of Emotional speech in those with Parkinson's disease.	Random forests, naïve bayes and support vector machines	73%	Recorded speaking short statements
M. Capecci∗, L. Ciabattoni et al [52]	2019	Emotion Recognition System Based on Machine Learning	Clinical scale and commercial emotion identification software were utilised.	NA	NA
Anusri U et.al. [53]	2021	Early detection of PD using facial emotional intelligence	Alex net and VGG16	96.5%	PPMI dataset
Justyna Skiba´nska [54]	2021	Analysis of Emotional changes during pronunciation speed exercise	XG Boost	69%	They made self-dataset
Konstantino s Sechidis et.al [55]	2021	Assessment of PD speech characteristics	Machine learning	NA	NA

Muhammad Najam Dar et.al [56]	2022	EEG based Emotional classification	ELM (extreme learning machine)	83.2%	Cross dataset

This section summarises the researcher's current work and provides a tabular comparison with the recommended systems. Nowadays, EI is critical to how we respond to what life throws at us. It is also a necessary component of compassion and recognising the deeper motivations behind others' behaviours. When coping with stressful events such as conflict, change, and barriers, EI is very helpful.

Based on the literature review we propose the following taxonomy:

A taxonomy of detection of Parkinson's disease using Emotional Intelligence is a categorization system that describes different techniques and approaches used in the field. Some of the possible categories in the taxonomy of detection of Parkinson's disease using Emotional Intelligence are:

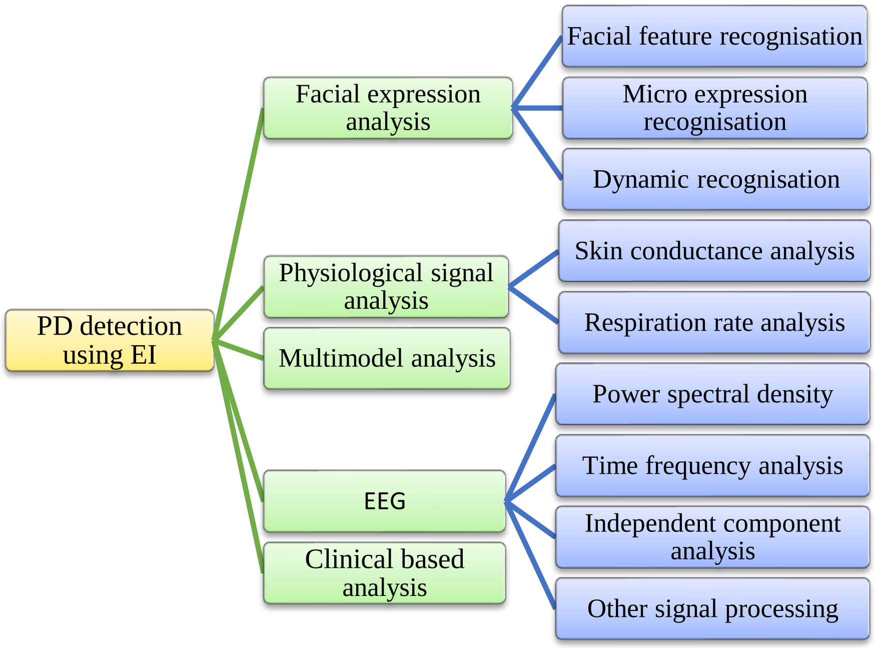

Figure 4. Taxonomy of PD Detection using Emotional Intelligence

• **Facial Expression Analysis**: This involves using computer vision and machine learning techniques to analyse changes in facial expressions and movements, which are associated with Parkinson's disease. The data type used for Facial Expression Analysis in the detection of Parkinson's disease using Emotional Intelligence is image and video data. This can include still images or videos of the face, captured either in a controlled laboratory environment or in a real-world setting. The image and video data are then processed using computer vision algorithms, such as feature extraction, face detection and landmark detection, to extract relevant information about the facial expressions and movements. These features are then analysed for changes in their appearance, shape, and movement that are indicative of Parkinson's disease [53] .Various methods involved in recognizing the facial expressions are;(I) **Facial feature recognition**: This category includes the ability to identify and differentiate specific facial features associated with different emotions. This skill helps individuals with EI to more accurately identify emotions expressed through facial expressions. Studies have shown that individuals with high levels of EI are better able to recognize and differentiate facial features associated with different emotions (Scherer et al., 2013) [57].(II)**Micro-**

expression recognition: This category includes the ability to recognize and interpret subtle and brief facial expressions that convey fleeting emotions. Micro-expressions are often automatic and involuntary, making them difficult to recognize. However, individuals with high EI can develop the ability to recognize these expressions and use them to more accurately interpret emotions in others. Research has shown that individuals with high EI are better able to recognize and interpret micro-expressions than those with lower EI (Matsumoto et al., 2016) [58] (III)**Dynamic recognition:** This category includes the ability to recognize and interpret the changing emotions expressed through facial expressions over time. Individuals with EI can develop dynamic recognition skills to more accurately interpret complex emotional expressions that evolve over time. Research has shown that individuals with high EI are better able to recognize and interpret dynamic emotional expressions than those with lower EI (Hess & Blairy, 2001) [59].

• **Electroencephalography (EEG):** This involves measuring the electrical activity of the brain using electrodes placed on the scalp, and using machine learning techniques to analyse the EEG signals for patterns that are indicative of Parkinson's disease [60].The data type used in Electroencephalography (EEG) Analysis is EEG signals or brainwaves, which are recorded and analysed using electrodes placed on the scalp. The EEG signals are then pre-processed, such as removing noise and artifacts, and then fed into machine learning algorithms for further analysis [61]. The goal is to identify patterns in the EEG signals that are indicative of Parkinson's disease, and this requires selecting appropriate features, such as frequency and power, and using appropriate machine learning techniques, such as neural networks, support vector machines, and neural networks. Based on the EEG data, this analysis produces a diagnosis or prognosis of Parkinson's disease[60], [62]. Several approaches are utilised to examine EEG data in Electroencephalography (EEG) Analysis for Parkinson's disease identification., including (I)Power spectral density analysis: This method involves calculating the power spectral density of the EEG signals to identify changes in the frequency distribution of the signals, which are associated with Parkinson's disease [63].(II)**Time-frequency analysis:** This method involves analysing the time-frequency representation of the EEG signals to identify changes in the frequency content of the signals over time [64].(III)**Independent Component Analysis (ICA):** This method involves separating the EEG signals into independent components and analysing the properties of each component to identify patterns that are indicative of Parkinson's disease [65]. (IV) **Other signal processing techniques:** Other signal processing techniques, such as wavelet transformations, linear discriminant analysis (LDA), and principal component analysis (PCA), may also be used to analyse EEG recordings and find patterns related to Parkinson's disease [66].

• **Physiological Signal Analysis:** This involves analysing signals from the body, such as heart rate variability, skin conductance, and respiration rate, to detect changes in emotional. In the Physiological Signal Analysis category, several methods can be used to analyse the signals obtained from the body. One commonly used method is Heart Rate Variability (HRV) analysis, where the variation in time intervals between heart beats is analysed to understand the changes in autonomic nervous system activity[67]. Another method is Skin Conductance Analysis, which involves measuring the electrical conductance of the skin to detect changes in sweat gland activity, which is an indicator of emotional arousal. Respiration rate analysis is also used to measure changes in breathing patterns, which are often associated with changes in emotional states. Machine learning algorithms, such as random forests decision trees, and support vector machines, can be used to analyse these signals and classify them into different emotional states.

- **Multi-modal analysis:** Multi-modal analysis can use a combination of techniques such as feature extraction, feature selection, dimensionality reduction, and machine learning algorithms such as decision trees, support vector machines, random forests, and deep neural networks. These techniques help to combine the information from multiple sources, to increase the robustness of the model and improve its performance[68]. Additionally, hybrid models that use a combination of machine learning and rule-based systems can also be used in multi-modal analysis. The specific methods used would depend on the specific goals and requirements of the project, as well as the data available. For example, a study by Goldenberg et al. (2017) published in the journal "Movement Disorders" found that EI was related to several important outcomes in PD, including motor symptoms, cognitive function, and quality of life. These findings highlight the potential value of considering EI in the management of PD and demonstrate the potential of multimodal analysis to inform the development of more personalized treatment plans for individual patients [69] .

- **Clinical outcomes-based analysis:** This category involves the use of patient-reported outcomes, such as quality of life, depression, and anxiety scores, to assess the effectiveness of the emotional intelligence-based approach in detecting Parkinson's disease. Clinical outcomes-based analysis typically involves statistical methods such as regression analysis and classification algorithms to analyse the relationship between the patient-reported outcomes and Parkinson's disease status [70].The specific method used may vary depending on the research question, the type of data available, and the type of analysis desired. Some common methods used in this category include logistic regression, linear regression decision trees, and neural networks and support vector machines. The purpose is to evaluate the validity and reliability of the emotional intelligence-based method by using patient-reported outcomes to create accurate predictions regarding Parkinson's disease state [71].

6. Open research challenges

Research challenges for the detection of Parkinson's disease can include the following:
(I) Inadequate or limited data availability. (II)Data quality and variability: The quality and variability of emotional intelligence data collected from individuals with Parkinson's disease can also present challenges in developing accurate models. This can include issues with measurement precision, as well as individual differences in emotional expressions. (III)Model interpretability: Interpreting the results of models trained on Emotional Intelligence data can be challenging, making it difficult to understand the underlying factors contributing to Parkinson's disease and to develop effective interventions.(IV)Ethical and privacy considerations: The collection and use of Emotional Intelligence data for the detection of Parkinson's disease also raises ethical and privacy concerns, such as the potential for discrimination based on emotional expressions and the security of sensitive personal data.(V)Variability in emotional expressions: Emotional expressions can be highly variable and can be influenced by many factors, such as mood, environment, and cultural background. This variability can make it difficult to accurately detect Parkinson's disease using emotional intelligence. (VI) Current Parkinson's disease detection methods, such as EEG and face recognition, have limits in terms of accuracy and scalability. This makes it difficult to create models that are both accurate and generally applicable.

Conclusion

Parkinson's disease can have a major influence on a person's Emotional Intelligence. The use of Emotional Intelligence techniques for Parkinson's disease detection has shown promising results, with the potential to complement or even surpass the accuracy of traditional biomarker-based approaches. Emotional intelligence-based approaches offer a non-invasive, cost-effective, and patient-centered approach to detecting PD, which may be especially useful in early-stage diagnosis and long-term monitoring of the disease. Further research is needed to validate and determine the efficacy of this approach. EI perspective has the potential to improve the accuracy of PD detection and enhance the quality of life for individuals with PD, and it represents an important area for future research in this field.

References

1. "Figure 1: Deep Brain Stimulation (DBS) [7]," 2020.
2. M. A. Nalls *et al.*, "Large-scale meta-analysis of genome-wide association data identifies six new risk loci for Parkinson's disease," *Nat Genet*, vol. 46, no. 9, pp. 989–993, 2014, doi: 10.1038/ng.3043.
3. N. Ball, W. P. Teo, S. Chandra, and J. Chapman, "Parkinson's disease and the environment," *Frontiers in Neurology*, vol. 10. Frontiers Media S.A., Mar. 19, 2019. doi: 10.3389/fneur.2019.00218.
4. P. Maiti, J. Manna, G. L. Dunbar, P. Maiti, and G. L. Dunbar, "Current understanding of the molecular mechanisms in Parkinson's disease: Targets for potential treatments," *Translational Neurodegeneration*, vol. 6, no. 1. BioMed Central Ltd., 2017. doi: 10.1186/s40035-017-0099-z.
5. "Who gets Parkinson disease?", doi: 10.1503/cmaj.151179/-/DC1.
6. "Detection of Parkinson Disease in Brain MRI using Convolutional Neural Network." [Online]. Available: www.dicomapps.com/dicomtojpeg/index.html.
7. E. M. Khedr, A. A. Abdelrahman, Y. Elserogy, A. F. Zaki, and A. Gamea, "Depression and anxiety among patients with Parkinson's disease: frequency, risk factors, and impact on quality of life," *Egyptian Journal of Neurology, Psychiatry and Neurosurgery*, vol. 56, no. 1, Dec. 2020, doi: 10.1186/s41983-020-00253-5.
8. M. T. M. Prenger, R. Madray, K. van Hedger, M. Anello, and P. A. Macdonald, "Social Symptoms of Parkinson's Disease," *Parkinson's Disease*, vol. 2020. Hindawi Limited, 2020. doi: 10.1155/2020/8846544.
9. G. Dirnberger and M. Jahanshahi, "Executive dysfunction in Parkinson's disease: A review," in *Journal of Neuropsychology*, Sep. 2013, pp. 193–224. doi: 10.1111/jnp.12028.
10. I. Nissar, W. A. Mir, Izharuddin, and T. A. Shaikh, "Machine Learning Approaches for Detection and Diagnosis of Parkinson's Disease - A Review," in *2021 7th International Conference on Advanced Computing and Communication Systems, ICACCS 2021*, Institute of Electrical and Electronics Engineers Inc., Mar. 2021, pp. 898–905. doi: 10.1109/ICACCS51430.2021.9441885.
11. C. Sampaio *et al.*, "Pardoprunox in early Parkinson's disease: Results from 2 large, randomized double-blind trials," *Movement Disorders*, vol. 26, no. 8, pp. 1464–1476, Jul. 2011, doi: 10.1002/mds.23590.
12. SSN College of Engineering. Department of Biomedical Engineering, SSN College of Engineering. Centre for Healthcare Technologies, and Institute of Electrical and Electronics Engineers, *ICBSII-2018 : proceedings of the 4th International Conference on Biosignals, Images and Instrumentation : 22nd-24th March 2018*.

13. N. Ball, W. P. Teo, S. Chandra, and J. Chapman, "Parkinson's disease and the environment," *Frontiers in Neurology*, vol. 10. Frontiers Media S.A., Mar. 19, 2019. doi: 10.3389/fneur.2019.00218.
14. J. A. Driver, G. Logroscino, J. M. Gaziano, and T. Kurth, "Incidence and remaining lifetime risk of Parkinson disease in advanced age," 2009.
15. C. Klein and A. Westenberger, "Genetics of Parkinson's disease," *Cold Spring Harb Perspect Med*, vol. 2, no. 1, 2012, doi: 10.1101/cshperspect.a008888.
16. N. Ball, W. P. Teo, S. Chandra, and J. Chapman, "Parkinson's disease and the environment," *Frontiers in Neurology*, vol. 10. Frontiers Media S.A., Mar. 19, 2019. doi: 10.3389/fneur.2019.00218.
17. I. Cova and A. Priori, "Diagnostic biomarkers for Parkinson's disease at a glance: where are we?," *Journal of Neural Transmission*, vol. 125, no. 10. Springer-Verlag Wien, pp. 1417–1432, Oct. 01, 2018. doi: 10.1007/s00702-018-1910-4.
18. R. G. Burciu *et al.*, "Progression marker of Parkinson's disease: A 4-year multi-site imaging study," *Brain*, vol. 140, no. 8, pp. 2183–2192, Aug. 2017, doi: 10.1093/brain/awx146.
19. F. L. Pagan *et al.*, "Pharmacokinetics and pharmacodynamics of a single dose Nilotinib in individuals with Parkinson's disease," *Pharmacol Res Perspect*, vol. 7, no. 2, Apr. 2019, doi: 10.1002/prp2.470.
20. M. Hariharan, K. Polat, and R. Sindhu, "A new hybrid intelligent system for accurate detection of Parkinson's disease," *Comput Methods Programs Biomed*, vol. 113, no. 3, pp. 904–913, Mar. 2014, doi: 10.1016/j.cmpb.2014.01.004.
21. D. Smajlovic and O. C. Ibrahimagic, "Transcranial Brain Sonography in Parkinson's Disease and Other Parkinsonian Disorders: a Hospital Study from Tuzla, Bosnia and Herzegovina," *Med Arch*, vol. 71, no. 4, pp. 261–264, Aug. 2017, doi: 10.5455/medarh.2017.71.261-264.
22. A. Bhan, S. Kapoor, M. Gulati, and A. Goyal, "Early diagnosis of parkinson's disease in brain MRI using deep learning algorithm," in *Proceedings of the 3rd International Conference on Intelligent Communication Technologies and Virtual Mobile Networks, ICICV 2021*, Institute of Electrical and Electronics Engineers Inc., Feb. 2021, pp. 1467–1470. doi: 10.1109/ICICV50876.2021.9388571.
23. V. Berti, A. Pupi, and L. Mosconi, "PET/CT in diagnosis of movement disorders," *Ann N Y Acad Sci*, vol. 1228, no. 1, pp. 93–108, 2011, doi: 10.1111/j.1749-6632.2011.06025.x.
24. G. Pahuja, T. N. Nagabhushan, and B. Prasad, "Early detection of parkinson's disease by using SPECT imaging and biomarkers," *Journal of Intelligent Systems*, vol. 29, no. 1, pp. 1329–1344, Jan. 2020, doi: 10.1515/jisys-2018-0261.
25. L. Wang, Q. Zhang, H. Li, and H. Zhang, "SPECT molecular imaging in Parkinson's disease," *Journal of Biomedicine and Biotechnology*, vol. 2012. 2012. doi: 10.1155/2012/412486.
26. L. Ramig, A. Halpern, J. Spielman, C. Fox, and K. Freeman, "Speech treatment in Parkinson's disease: Randomized controlled trial (RCT)," *Movement Disorders*, vol. 33, no. 11, pp. 1777–1791, Nov. 2018, doi: 10.1002/mds.27460.
27. D. Y. Lee *et al.*, "Analysis of Temporal Change in Voice Quality After Thyroidectomy: Single-institution Prospective Study," *Journal of Voice*, vol. 31, no. 2, pp. 195–201, Mar. 2017, doi: 10.1016/j.jvoice.2016.04.017.
28. A. Sarker and A. Pramanik, "Parkinson's Disease Detection from Voice and Speech Data Using Machine Learning," 2020. [Online]. Available: https://www.researchgate.net/publication/347520593
29. E. Rovini, C. Maremmani, and F. Cavallo, "How wearable sensors can support parkinson's disease diagnosis and treatment: A systematic review," *Frontiers in Neuroscience*, vol. 11, no. OCT. Frontiers Media S.A., Oct. 06, 2017. doi: 10.3389/fnins.2017.00555.

30. L. di Biase *et al.*, "Gait analysis in parkinson's disease: An overview of the most accurate markers for diagnosis and symptoms monitoring," *Sensors (Switzerland)*, vol. 20, no. 12. MDPI AG, p. 1, Jun. 01, 2020. doi: 10.3390/s20123529.
31. T. M. Buchwitz, F. Maier, A. Greuel, and C. Eggers, "Improving Self-Awareness of Motor Symptoms in Patients With Parkinson's Disease by Using Mindfulness – A Study Protocol for a Randomized Controlled Trial," *Front Psychol*, vol. 11, Apr. 2020, doi: 10.3389/fpsyg.2020.00743.
32. C. Hellqvist, C. Berterö, N. Dizdar, M. Sund-Levander, and P. Hagell, "Self-Management Education for Persons with Parkinson's Disease and Their Care Partners: A Quasi-Experimental Case-Control Study in Clinical Practice," *Parkinsons Dis*, vol. 2020, 2020, doi: 10.1155/2020/6920943.
33. F. Kitsios, E. Papageorgiou, M. Kamariotou, N. A. Perifanis, and M. A. Talias, "Emotional intelligence with the gender perspective in health organizations managers," *Heliyon*, vol. 8, no. 11, Nov. 2022, doi: 10.1016/j.heliyon.2022.e11488.
34. L. Ricciardi *et al.*, "Facial emotion recognition and expression in Parkinson's disease: An emotional mirror mechanism?," *PLoS One*, vol. 12, no. 1, Jan. 2017, doi: 10.1371/journal.pone.0169110.
35. I. Enrici *et al.*, "Emotion processing in Parkinson's disease: A three-level study on recognition, representation, and regulation," *PLoS One*, vol. 10, no. 6, Jun. 2015, doi: 10.1371/journal.pone.0131470.
36. I. Sotgiu and M. L. Rusconi, "Investigating emotions in Parkinson's disease: what we know and what we still don't know," *Front Psychol*, vol. 4, Jun. 2013, doi: 10.3389/fpsyg.2013.00336.
37. S. P. Coundouris, A. G. Adams, and J. D. Henry, "Empathy and theory of mind in Parkinson's disease: A meta-analysis," *Neuroscience and Biobehavioral Reviews*, vol. 109. Elsevier Ltd, pp. 92–102, Feb. 01, 2020. doi: 10.1016/j.neubiorev.2019.12.030.
38. N. S. Schutte *et al.*, "On the dimensional structure of emotional intelligence," 1998. [Online]. Available: www.elsevier.com/locate/paid
39. J. D. Mayer, P. Salovey, and D. R. Caruso, "Emotional intelligence: Theory, findings, and implications," *Psychological Inquiry*, vol. 15, no. 3. Routledge, pp. 197–215, 2004. doi: 10.1207/s15327965pli1503_02.
40. "Detection of Parkinson Disease in Brain MRI using Convolutional Neural Network." [Online]. Available: www.dicomapps.com/dicomtojpeg/index.html.
41. Institute of Electrical and Electronics Engineers, *2018 IEEE Nuclear Science Symposium and Medical Imaging Conference Proceedings (NSS/MIC) : conference proceedings : 10 -17 November 2018, International Convention Centre, Sydney, Australia.*
42. Institute of Electrical and Electronics Engineers, *CEIT 2018 : 2018 6th International Conference on Control, Engineering & Information Technology (CEIT) : 25-27 October 2018, Istanbul, Turkey.*
43. P. D. Acton and A. Newberg, "Artificial neural network classifier for the diagnosis of Parkinson's disease using [99mTc]TRODAT-1 and SPECT," *Phys Med Biol*, vol. 51, no. 12, pp. 3057–3066, Jun. 2006, doi: 10.1088/0031-9155/51/12/004.
44. C. Asia-Pacific Signal and Information Processing Association. Annual Summit and Conference (2019 : Lanzhou Shi, Asia-Pacific Signal and Information Processing Association, IEEE Signal Processing Society, and Institute of Electrical and Electronics Engineers, *2019 Asia-Pacific Signal and Information Processing Association Annual Summit and Conference (APSIPA ASC).*
45. S. S. Iyengar, V. Saxena, IEEE Computer Society. Technical Committee on Parallel Processing, Institute of Electrical and Electronics Engineers, Jaypee Institute of Information Technology

University, and University of Florida. College of Engineering, *2019 Twelfth International Conference on Contemporary Computing (IC3-2019) : 8-10 August 2019, Jaypee Institute of Information Technology, Noida, India*.
46. R. M. Sadek *et al.*, "Parkinson's Disease Prediction Using Artificial Neural Network," 2019. [Online]. Available: www.ijeais.org/ijahmr
47. S. Krishnagopal, R. von Coelln, L. M. Shulman, and M. Girvan, "Identifying and predicting Parkinson's disease subtypes through trajectory clustering via bipartite networks," *PLoS One*, vol. 15, no. 6, Jun. 2020, doi: 10.1371/journal.pone.0233296.
48. Z. Karapinar Senturk, "Early diagnosis of Parkinson's disease using machine learning algorithms," *Med Hypotheses*, vol. 138, May 2020, doi: 10.1016/j.mehy.2020.109603.
49. H. Modi, J. Hathaliya, M. S. Obaidiat, R. Gupta, and S. Tanwar, "Deep Learning-based Parkinson disease Classification using PET Scan Imaging Data," in *2021 IEEE 6th International Conference on Computing, Communication and Automation, ICCCA 2021*, Institute of Electrical and Electronics Engineers Inc., 2021, pp. 837–841. doi: 10.1109/ICCCA52192.2021.9666251.
50. B. Benhala, Jāmiʻat al-Mawlāy Ismāʻīl. Faculty of Sciences, Institute of Electrical and Electronics Engineers. Morocco Section, and Institute of Electrical and Electronics Engineers, *IRASET'2020 : 2020 1st International Conference on Innovative Research in Applied Science, Engineering and Technology (IRASET) : March 19-20, 2020, Faculty of Sciences, Meknes University of Moulay Ismail - Morocco*.
51. S. Zhao, F. Rudzicz, L. G. Carvalho, C. Márquez-Chin, and S. Livingstone, "AUTOMATIC DETECTION OF EXPRESSED EMOTION IN PARKINSON'S DISEASE."
52. G. Velikić, C. Gross, and Institute of Electrical and Electronics Engineers, *Proceedings 2019 IEEE 9th International Conference on Consumer Electronics (ICCE-Berlin)*.
53. U. Anusri, G. Dhatchayani, Y. Princely Angelinal, and S. Kamalraj, "An Early Prediction of Parkinson's Disease Using Facial Emotional Recognition," in *Journal of Physics: Conference Series*, IOP Publishing Ltd, Jun. 2021. doi: 10.1088/1742-6596/1937/1/012058.
54. Institute of Electrical and Electronics Engineers, *ICUMT 2020 : the 12th International Congress on Ultra Modern Telecommunications and Control Systems : 5-7 October, online*.
55. K. Sechidis, R. Fusaroli, J. R. Orozco-Arroyave, D. Wolf, and Y. P. Zhang, "A machine learning perspective on the emotional content of Parkinsonian speech," *Artif Intell Med*, vol. 115, May 2021, doi: 10.1016/j.artmed.2021.102061.
56. M. N. Dar, M. U. Akram, R. Yuvaraj, S. Gul Khawaja, and M. Murugappan, "EEG-based emotion charting for Parkinson's disease patients using Convolutional Recurrent Neural Networks and cross dataset learning," *Comput Biol Med*, vol. 144, May 2022, doi: 10.1016/j.compbiomed.2022.105327.
57. A. Moors, "Appraisal Theory of Emotion," in *Encyclopedia of Personality and Individual Differences*, Springer International Publishing, 2017, pp. 1–9. doi: 10.1007/978-3-319-28099-8_493-1.
58. D. Matsumoto and H. C. Hwang, "Microexpressions differentiate truths from lies about future malicious intent," *Front Psychol*, vol. 9, no. DEC, Dec. 2018, doi: 10.3389/fpsyg.2018.02545.
59. U. Hess and S. Blairy, "Facial mimicry and emotional contagion to dynamic emotional facial expressions and their influence on decoding accuracy," 2001.
60. H. Marzbani, H. R. Marateb, and M. Mansourian, "Methodological note: Neurofeedback: A comprehensive review on system design, methodology and clinical applications," *Basic Clin Neurosci*, vol. 7, no. 2, pp. 143–158, Mar. 2016, doi: 10.15412/j.bcn.03070208.

61. "Ha n d b o o k o f E E G I N T E R P R E TAT I O N."
62. K. H. Chang *et al.*, "Evaluating the Different Stages of Parkinson's Disease Using Electroencephalography With Holo-Hilbert Spectral Analysis," *Front Aging Neurosci*, vol. 14, May 2022, doi: 10.3389/fnagi.2022.832637.
63. T. Heida, E. C. Wentink, and E. Marani, "Power spectral density analysis of physiological, rest and action tremor in Parkinson's disease patients treated with deep brain stimulation," *J Neuroeng Rehabil*, vol. 10, no. 1, 2013, doi: 10.1186/1743-0003-10-70.
64. A. M. Maitín *et al.*, "Time Series Analysis Applied to EEG Shows Increased Global Connectivity during Motor Activation Detected in PD Patients Compared to Controls," 2020, doi: 10.3390/app1.
65. C. Zhou *et al.*, "Structural Covariance Network Disruption and Functional Compensation in Parkinson's Disease," *Front Aging Neurosci*, vol. 12, Jul. 2020, doi: 10.3389/fnagi.2020.00199.
66. A. Subasi and M. I. Gursoy, "EEG signal classification using PCA, ICA, LDA and support vector machines," *Expert Syst Appl*, vol. 37, no. 12, pp. 8659–8666, 2010, doi: 10.1016/j.eswa.2010.06.065.
67. F. Shaffer and J. P. Ginsberg, "An Overview of Heart Rate Variability Metrics and Norms," *Frontiers in Public Health*, vol. 5. Frontiers Media S.A., Sep. 28, 2017. doi: 10.3389/fpubh.2017.00258.
68. J. Filipe, A. Ghosh, R. O. Prates, and L. Zhou, "Editorial Board Members." [Online]. Available: http://www.springer.com/series/7899
69. M. Faundez-Zanuy *et al.*, "A multimodal approach for parkinson disease analysis," *Smart Innovation, Systems and Technologies*, vol. 37, pp. 311–318, 2015, doi: 10.1007/978-3-319-18164-6_30.
70. C. Gao *et al.*, "Model-based and model-free machine learning techniques for diagnostic prediction and classification of clinical outcomes in Parkinson's disease," *Sci Rep*, vol. 8, no. 1, Dec. 2018, doi: 10.1038/s41598-018-24783-4.
71. K. Dashtipour, J. J. Chen, C. Kani, K. Bahjri, and M. Ghamsary, "Clinical Outcomes in Patients with Parkinson's Disease Treated with a Monoamine Oxidase Type-B inhibitor: A Cross-Sectional, Cohort Study," *Pharmacotherapy*, vol. 35, no. 7, pp. 681–686, Jul. 2015, doi: 10.1002/phar.1611.